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Initial Morphologic Evolution of Perdido Key Berm Nourishment, Florida

by **Ping Wang, Katherine E. Brutsche, Tanya M. Beck, Julie D. Rosati, and Linda S. Lillycrop**

PURPOSE: This Coastal and Hydraulics Engineering Technical Note (CHETN) documents the initial morphologic evolution of the Perdido Key, FL, swash-zone berm based on beach-nearshore profile, sediment samples, and nearshore wave data collected during the first six months after berm construction.

INTRODUCTION: The US Army Corps of Engineers (USACE), Mobile District, dredged the navigation channel at Pensacola Pass, FL, from November 2011 to January 2012 and placed the 520,000 cubic yards (yd^3) of dredged sand as a swash-zone berm nearshore of Perdido Key, FL. Beach quality sands are a valuable resource within the coastal zone in maintaining regional sediment balance. Compared to a typical beach fill (or direct beach placement), nearshore berm placement (in this case a swash-zone berm) has advantages of being less costly with more lenient regulatory restrictions on sediment type and monitoring requirements (Hands and Allison 1991; McLellan and Kraus 1991). The Perdido Key berm was designed to be an active berm that would quickly mobilize sediments in the energetic swash zone. The goal was to beneficially use maintenance dredged material to nourish the littoral environment adjacent to Pensacola Pass, and to have an immediate impact on the narrow subaerial beach. This CHETN documents the initial morphological evolution of the Perdido Key swash-zone berm placement based on analysis of beach-nearshore profiles, sediment samples, and nearshore wave data.

STUDY AREA AND BERM CONSTRUCTION: The eastern portion of Perdido Key, including the present study area, was nourished in 1985 and 1989 (Dean et al. 1995). The 1985 beach nourishment was constructed to a berm height of +10.3 ft NAVD88, whereas the 1989 beach nourishment had a constructed berm height of +4.3 ft NAVD88 (Dean et al. 1995; Browder and Dean 2000). The 1989 nourishment also included a nearshore berm placed at roughly -22 ft NAVD88 with a crest height of roughly 5.7 ft.

The 2012 Perdido Key artificial berm was placed west of Pensacola Pass (Figure 1). This berm is different from all existing documented berms reviewed by Wang et al. (in preparation). The crest of this artificial berm was constructed at +3 ft NAVD88, which was just 1.3 ft below the elevation of the 1989 beach nourishment. Based on the NOAA Tide Station 8729840 at Pensacola, Mean Sea Level (MSL), Mean High Water (MHW), and Mean Higher High Water (MHHW) are at 0.30 ft, 0.91 ft, and 0.94 ft NAVD88, respectively. Therefore, the crest of the Perdido Key berm was located about 2 ft above MHHW. The sand was pumped onto the beach between Florida Department of Environmental Protection (FDEP) monuments R53 and R64 through a pipeline, and graded to an elevation of +3 ft NAVD88 (Figure 2).

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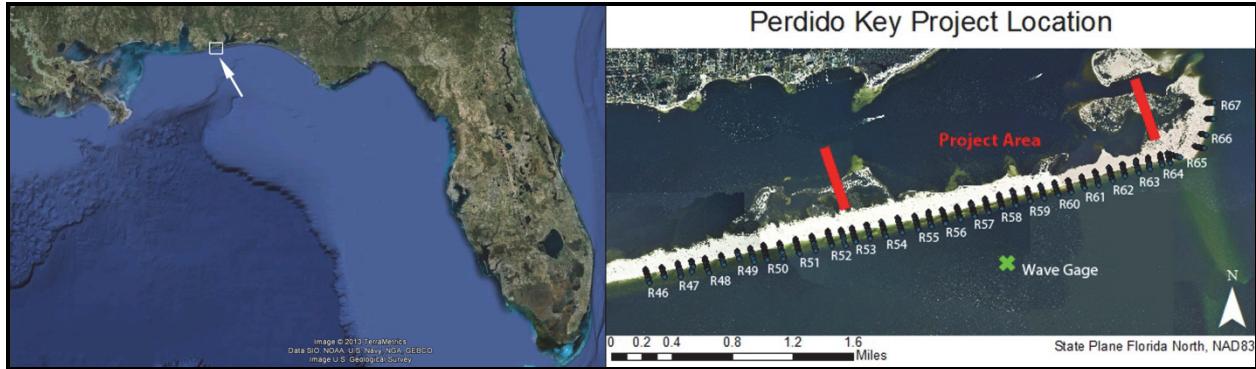


Figure 1. Study area with survey lines spaced roughly 500 ft apart. The surveyed profile between R-monuments is indicated by "0.5" (e.g., R55.5 denotes the line between R55 and R56. The west control area extends from R46 to R53). The east control area extends around the inlet from R64 to R67.



Figure 2. Berm construction: Sand is pumped onto the beach and graded (photo taken December 18, 2011).

METHODOLOGY: This study is based on beach-nearshore profiles, sediment samples, and wave data collected during the first 6 months following placement. Pre- (November 2011) and post-construction (January 2012) shore-perpendicular profile surveys were conducted by the Mobile District. The pre-construction survey included beach and offshore areas. The post-construction survey only included the beach portion. Additional profiles extending from +9 ft to -11 ft NAVD88 were surveyed bimonthly by the Coastal Research Laboratory at the University of South Florida (USF-CRL) following level-and-transit procedures using an electronic total survey station and a 12.5-ft survey rod. Surface sediment samples were collected before and after berm placement to examine the compatibility of native and nourished sand. Sediment samples were collected at various cross-shore locations extending from the dune edge to roughly 4 ft water depth. Sediment grain size was analyzed using standard sieves. Nearshore tide and wave conditions were measured using a PUV directional wave gauge, located roughly 2,000 ft from shoreline in 18 ft water depth (Figure 1).

OCEANOGRAPHIC AND METEOROLOGIC CONDITIONS: This area is prone to hurricane impacts and has had 3 major (category 3 or above) hurricanes pass within 50 nautical miles since 2000. Hurricane Ivan made landfall 30 miles west of Pensacola Pass in 2004 and had a tremendous impact on the study area (FDEP 2004). Dean et al. (1995) suggested that the elevation of the natural beach is about +6 ft NAVD88. Wang and Horwitz (2007) and Claudino-Sales et al. (2010) found that +6 ft NAVD88 is roughly the elevation of the overwash platforms associated with

Hurricane Ivan. Net longshore transport along the study area is toward the west at 40,000 to 75,000 yd³/yr with local reversal located just west of the inlet (Browder and Dean 2000).

The study area experiences small diurnal tides with spring tides ranging slightly over 2 ft and neap tides less than 1 ft (Figure 3). Meteorological conditions have a significant influence on water-level fluctuations. The average wave height during the study period was 1.8 ft, with a standard deviation of 1.2 ft. High waves occurred during the episodic passages of cold fronts in the winter and tropical storms in the summer.

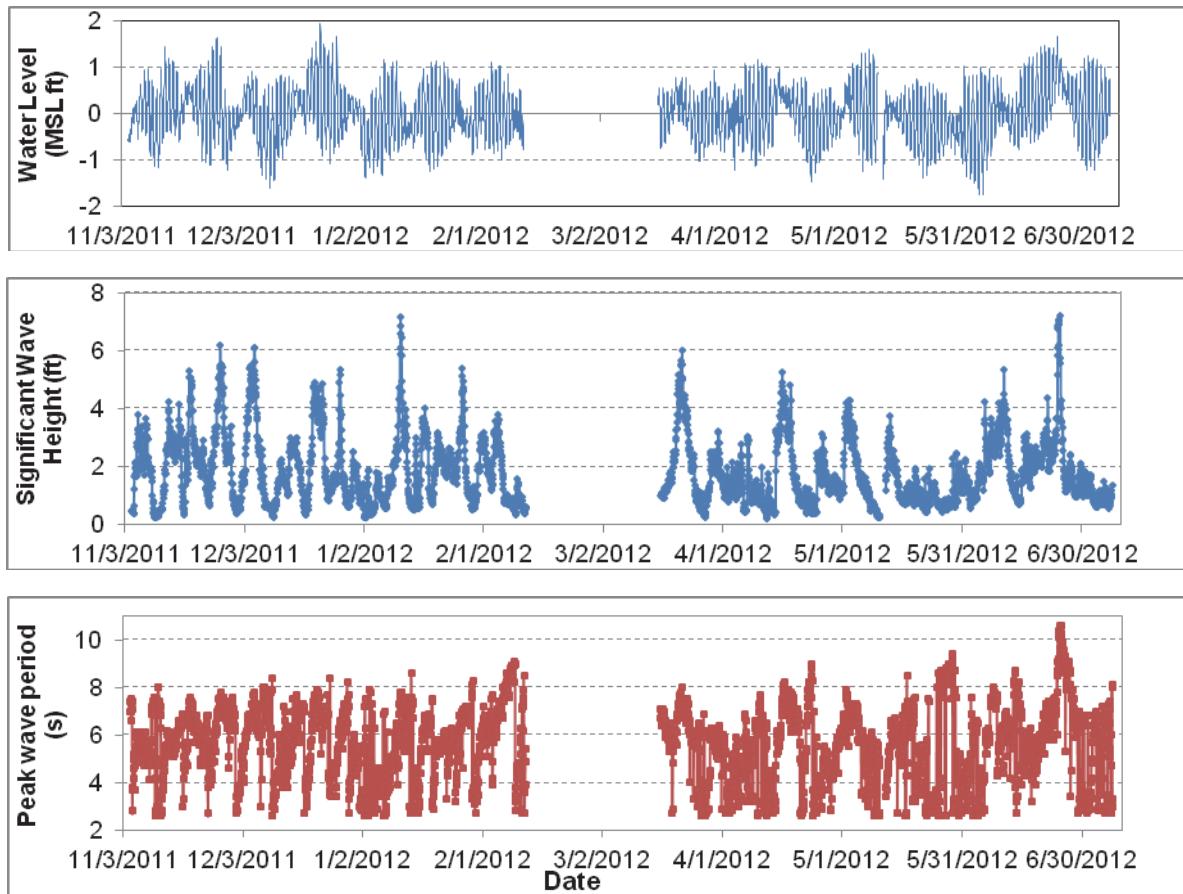


Figure 3. Water level (top), significant wave height, (middle), and peak wave period (bottom) measured during the study period. Wave gauge location is shown in Figure 1.

The highest wave of 7.2 ft, also occurred with the longest period of 10.6 s, and was the peak wave height measured during the distal passage of Tropical Storm (TS) Debby in late June 2012. An elevated water level of roughly 0.5 ft was measured. High wave events were more frequent during the winter (November to April) than during the summer (April to July). It is worth noting that based on NOAA wave buoy 42012 about 14 miles offshore of Perdido Pass (in water depth of 90 ft), three energetic events occurred between mid-February and mid-March when the CRL-USF nearshore wave gauge was out of power.

SEDIMENT CHARACTERISTICS: Sediment samples were collected and analyzed along 14 profiles before and after the berm construction. Three samples collected from the back-beach were

averaged across each sampling profile to provide a representative grain size of pre-placement and post-placement (Figure 4). Prior to placement, the average back-beach grain-size decreased from nearly 0.50 mm on the western side of the project to 0.34 mm at the eastern terminus of the island. All surface samples taken along the back-beach following construction of the berm indicated an alongshore, uniform grain size ranging from 0.32 to 0.39 mm of well-sorted, medium quartz sand.

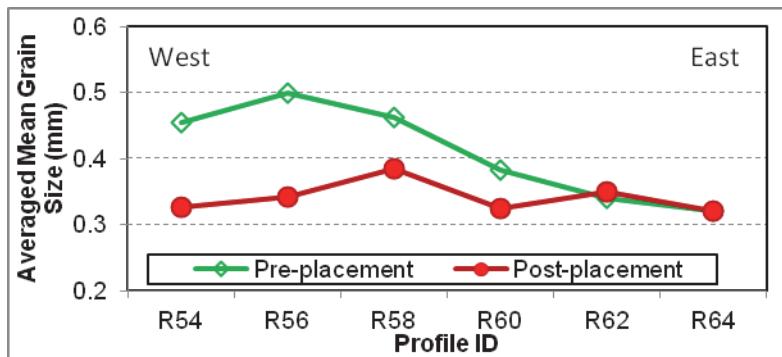


Figure 4. Comparison of the mean grain size between the native sediment (pre-placement, sampled Nov. 2011) and the placed sediment (sampled Jan. 2012).

MORPHOLOGICAL EVOLUTION: Morphologic evolution during the first 6 months was examined by comparing profiles surveyed before, immediately after, and 2, 4, and 6 months post-construction. Profile changes in the control areas (Figure 1) were compared with changes in the project area, to examine alongshore spreading of the berm material. Profile R58.5 provides a representative example of morphologic change in the middle of the project (Figure 5). The initial placement extended the shoreline roughly 250 ft seaward. The shoreline retreated landward nearly 100 ft during the first 2 months. As the shoreline moved landward, a berm crest developed over the placement. This natural berm crest was 2.0 ft higher than the constructed berm. This natural process of beach building was clearly illustrated by the substantial storm-berm development associated with the distal passage of TS Debby. A storm berm nearly 100-ft-wide with a crest of nearly +6 ft NAVD88 developed (Figures 5 and 6), and was measured along the entire project area with widths and heights varying alongshore.

Significantly more landward retreat of shoreline occurred during the first 2 months (Figure 7) near the western end of the berm as compared to the rest of the project (Figure 5). This is due to alongshore spreading of the placement material. The shoreline retreated landward over 120 ft or about half of the nourished width, followed by another 30 ft associated with TS Debby. The storm berm that developed during TS Debby was nearly 100-ft-wide and welded to the higher pre-placement beach (Figure 7). It was a different shape as compared to the morphology measured in the middle of the project.

The constructed berm at the eastern end of the project was roughly 150 ft wide, or about half of the width of the western portion. The berm width did not change significantly during the first 6 months (Figure 8). The shoreline retreated landward roughly 20 ft during the passage of TS Debby. A storm berm nearly 100 ft wide and up to +6 ft NAVD88 in elevation was developed. Compared to the western portion of the berm, the eastern end had smaller profile change, or erosion in this case. This may be attributed to some trapping of eastward sediment transport near the inlet due to the

local transport reversal induced by the ebb-tidal delta while the longshore spreading at the western end is further amplified by the net westward longshore transport.

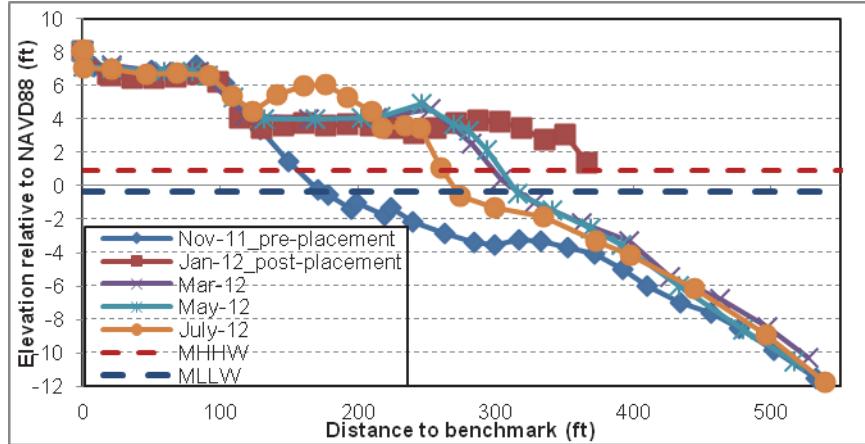


Figure 5. Time-series beach-nearshore profile at R58.5 in the middle of the berm project area. Location of the profile is shown in Figure 1.



Figure 6. Development of the storm berm approaching the elevation of pre-placement backbeach, after the distal passage of Tropical Storm Debby. Photo taken July 2012.

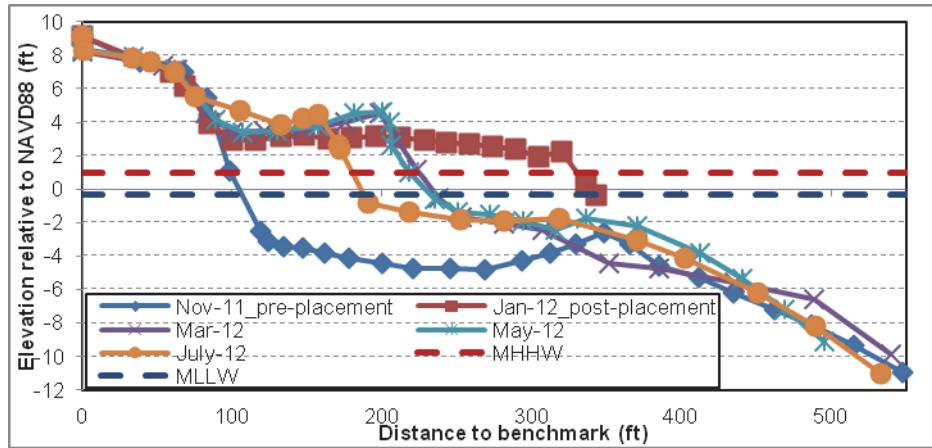


Figure 7. Time-series beach-nearshore profile at R54 at the western end of the berm project area. Location of the profile is shown in Figure 1.

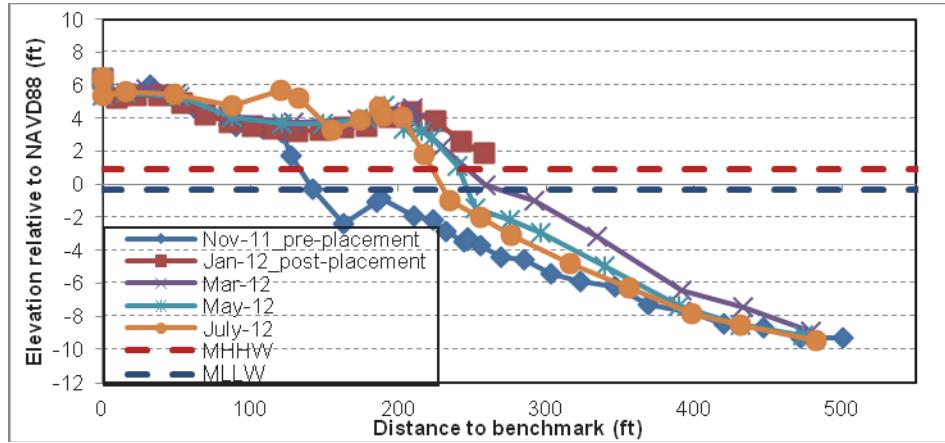


Figure 8. Time-series beach-nearshore profile at R63 at the eastern end of the berm project area. Location of the profile is shown in Figure 1.

Volume gain was measured at profile R52, 1,000 ft west of the artificial berm (Figure 9). Most sand-volume gain occurred in the subtidal zone, while the subaerial beach remained stable. The pre-placement profile shows a bar-trough morphology, with a 200-ft-wide trough up to 6 ft deep and a small bar. Six months later, much of the trough accumulated nearly 4 ft of sand and evolved into a shallow platform. The significant change occurred between May and July and is attributed to the passage of TS Debby.

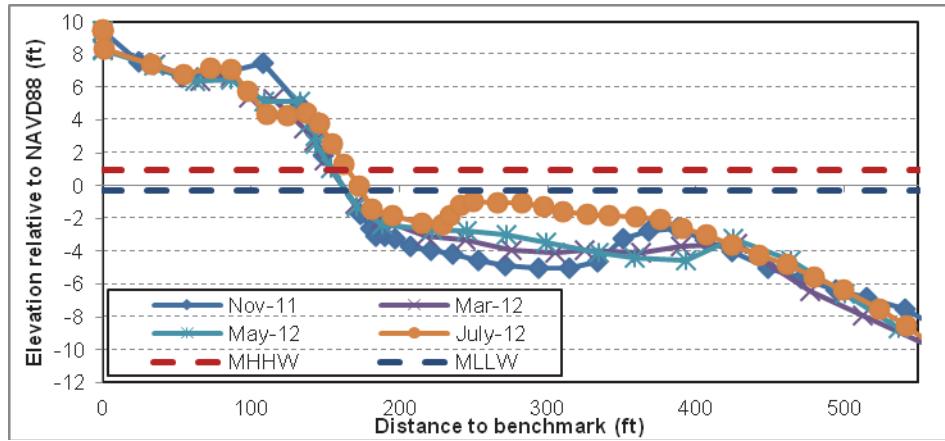


Figure 9. Time-series beach-nearshore control profile at R52, approximately 1,000 ft west of the berm project. Location of the profile is shown in Figure 1.

East of the berm, the shoreline extends north along the western shore of Pensacola Pass. Bathymetry along this stretch varies substantially, ranging from the steep slopes along the inlet to the extensive, shallow channel-margin linear bar (Figure 1). Overall, the profiles were stable during the 6-month period, as shown by profile R65 (Figure 10). A small amount of accumulation was measured over the dry beach, resulting in a roughly 20-ft seaward propagation of the active berm crest. Profile R65 extends perpendicular to the shoreline bend along the inlet (Figure 1). Profile R66.5 has a steep slope that extends into the channel (Figure 11). Little change occurred

along this and adjacent profiles, indicating minimal deposition of placement material along the inlet shoreline.

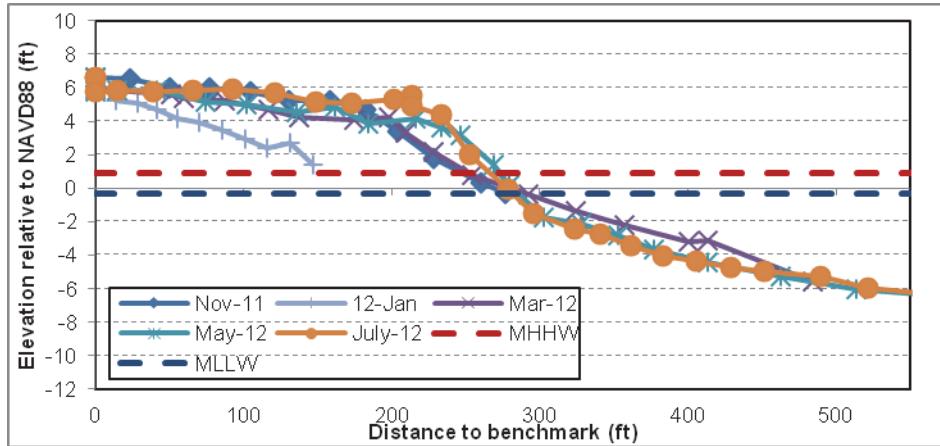


Figure 10. Time-series beach-nearshore profile at R65. Location of the profile is shown in Figure 1. This profile extends perpendicular to the sharp curve of the beach.

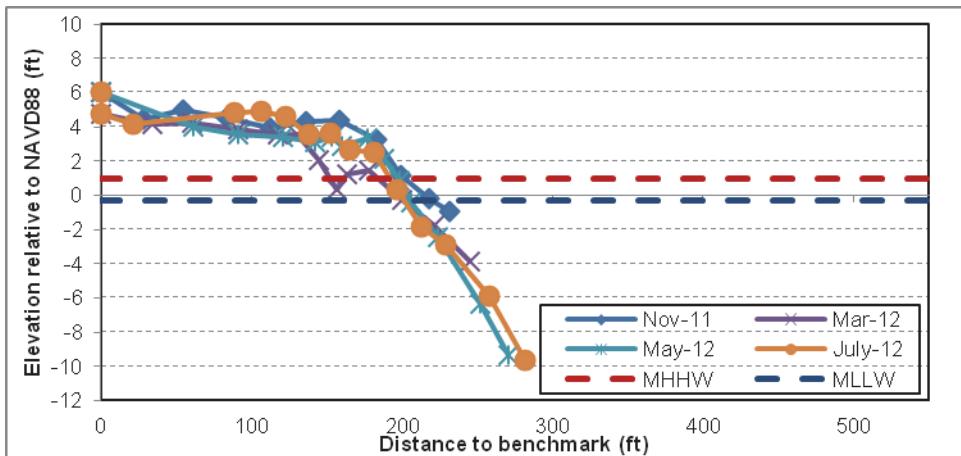


Figure 11. Time-series beach-nearshore profile at R66.5, along the western edge of Pensacola Pass. Location of the profile is shown in Figure 1.

Minimal changes over the backbeach occurred farther west of the artificial berm (Figure 12). Sand accumulation across the trough was measured between March and May 2012, while erosion was measured following TS Debby. TS Debby did not develop a storm berm along this location. This may be attributed to the fact that storm surge and waves did not transport material to the natural backbeach at an elevation of +6 ft NAVD88.

INITIAL SHORELINE AND VOLUME CHANGES: Shoreline along the artificial berm, represented here by the +2 ft NAVD88 contour (Figure 13), moved landward 50 to 150 ft in the first 6 months. The +2 ft contour coincides with the upper foreshore and does not fluctuate on the timescale of tidal cycles and should provide monthly to seasonal trend of shoreline change. Most landward retreat occurred in the first 2 months due to initial profile equilibration. TS Debby induced further landward shoreline movement and some of the eroded sand moved onshore and

deposited as a storm berm. The distance of shoreline retreat decreased eastward. Seaward shoreline advance occurred east of the berm. Accretion measured at profile R65 east of the berm was related to localized beach morphodynamics due to the curve in the shoreline (Figures 1 and 10) at the inlet, and does not represent changes at other locations. The shoreline to the west was stable.

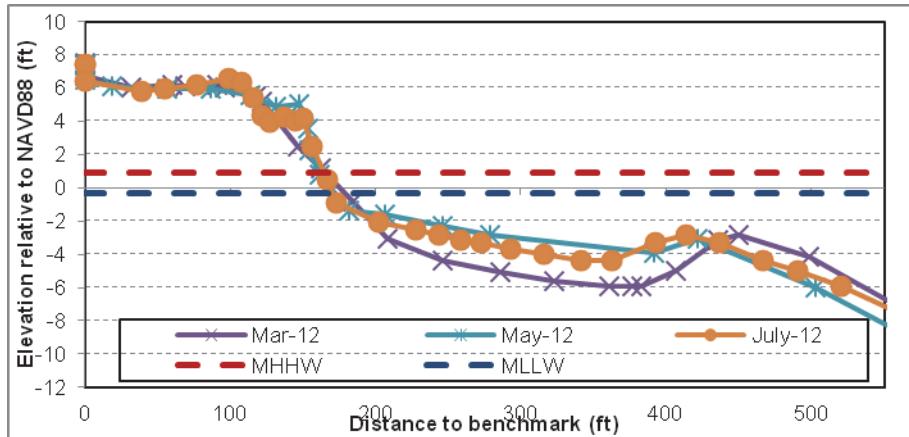


Figure 12. Time-series beach-nearshore profile at R48, approximately 5,000 ft west of the berm project area. Location of the profile is shown in Figure 1.

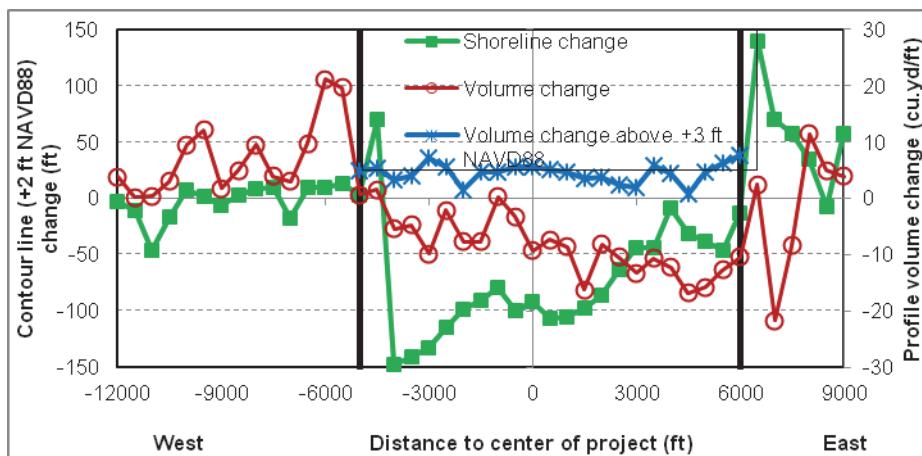


Figure 13. Shoreline (represented by +2 ft NAVD88 contour) and profile-volume change during the first 6 months. The berm project area is marked by the vertical lines.

The post-placement survey conducted in January 2012 included only the beach portion, and therefore was not used to calculate volume change. Volume change was calculated from the dune edge to -11 ft NAVD88 from March to July 2012. Almost all the profiles in the berm project area lost sand during the 4 months, totaling 91,000 yd^3 , or about 18 percent of the entire 520,000 yd^3 placement. Most profiles in the west control area gained sand, totaling 48,000 yd^3 or 9 percent of the placed sand. This suggests a westward alongshore spreading, consistent with direction of net longshore transport. Most profiles in the east control area directly adjacent to the inlet gained sand, except for profiles R65.5 and R65 (Figure 13). These two profiles are located at the sharp shoreline curve along the flood-marginal channel of Pensacola Pass where tidal currents may play a

dominant role in sand transport. The east control area had a net volume loss of 3,000 yd³, suggesting that a negligible volume of sand moved into the inlet. Figure 14 summarizes the volume change over the project area and the adjacent beaches. Over the entire study area, a net loss of 46,000 yd³, or nearly 9 percent of the total placement, was measured. Depositions in the offshore, into the inlet, and dispersion over the ebb delta are possible explanations of the net loss.

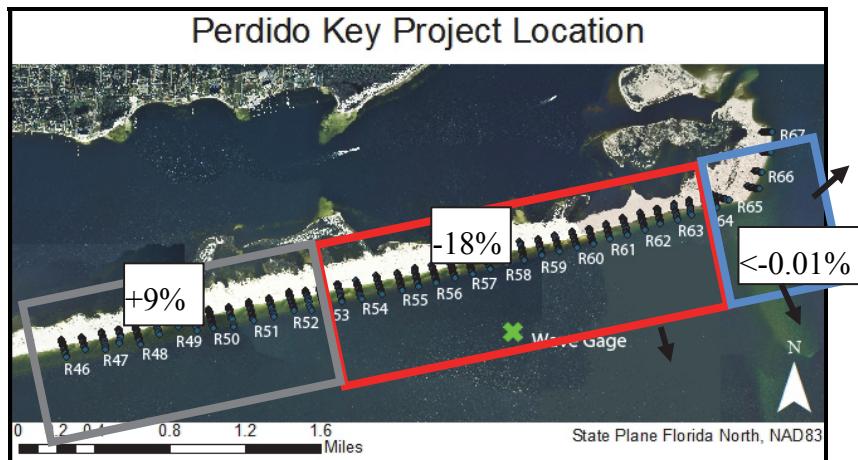


Figure 14. Summary of sand volume change in the project and control areas. Arrows pointing out of the boxes indicating possible volume loss not accounted by the survey.

Volume change above the +3 ft NAVD88 contour was calculated for the first 6 months from post-placement (January 2012) to July 2012. This represents the net onshore transport of the placed material. All the profiles within the berm project area gained sand during the first 6 months, averaging 4.5 yd³/ft (Figure 13). A total of 47,000 yd³ of sand, or 9 percent of the total placement, was gained on the backbeach in the morphologic form of a natural berm crest. The distal passage of TS Debby contributed to the development of the berm.

CONCLUSIONS: The Perdido Key berm was placed in the energetic swash zone with the expectation that the material would be rapidly mobilized and transported to nourish the entire beach profile. During the first 6 months, 50 to 150 ft landward retreat of shoreline (represented here by +2 ft NAVD88 contour) occurred. Although much of the sand moved offshore, 47,000 yd³ of sand, or 9 percent of the total placement, moved onshore. This was augmented by high swell waves from the distal passage of TS Debby, resulting in the accumulation of a storm berm roughly 100 ft wide and up to +6 ft NAVD88 in elevation, about 2 ft higher than the placed berm. During a 4-month period, westward alongshore spreading of 48,000 yd³ of sand was measured. Negligible volume change was measured east of the project, suggesting no significant amount of sand moved to the adjacent beach along Pensacola Pass. Comparing to the 91,000 yd³ loss from the project area, some sand may have been transported into the inlet, seaward of the -11 ft NAVD88 survey limit, or onto the ebb-tidal delta. The 6-month monitoring effort concluded that the swash-zone berm was rapidly mobilized and had provided roughly 10 percent of the nourished sand to the subaerial beach and another 10 percent of the sand to the downdrift beach, while a negligible amount of sand had moved into the adjacent inlet.

ADDITIONAL INFORMATION: This Coastal and Hydraulics Engineering Technical Note (CHETN) was prepared by Ping Wang and Katherine Brutsche, University of South Florida; and Tanya Beck, Julie Rosati, and Linda Lillycrop, US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory (ERDC-CHL). The authors acknowledge the data, information, and historical project knowledge provided by the Mobile District (USACE). It is a product of the Geomorphology work unit of the Coastal Inlets Research Program (CIRP) and Regional Sediment Management (RSM) program. These programs are conducted by ERDC-CHL, Vicksburg, MS. CIRP information can be obtained from Julie D. Rosati, USACE CIRP Program Manager, <http://cirp.usace.army.mil>. Information regarding RSM can be obtained from Linda S. Lillycrop, USACE RSM Program Manager, <http://rsm.usace.army.mil>. Questions regarding this CHETN may be addressed to Tanya Beck Tanya.M.Beck@usace.army.mil

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